CHAPTER

12

TABLE OF CONTENTS

MOVABLE BRIDGES

INTRODUCTION

Movable bridges are sometimes required for navigable waterways, where high level bridges are economically unfeasible, particularly urban areas where high level structures would cause excessive relocations. Particular attention must be given to geometric requirements for marine traffic clearance, and the fitting of the bridges and approaches to the site. The Coast Guard should be involved early in the design process (***See Exhibit "B", Coordination with Other Agencies)***

When the economics of a movable bridge are being considered, long term maintenance costs, as well as initial construction costs should be considered. The current and projected opening frequencies for marine traffic should be carefully weighted against the vehicular traffic volume.

SCOPE

This is a guide for the structural analysis and details involved in the plan preparation for movable bridges. It is also a guide for the economic comparison of a movable bridge to other alternatives. The AASHTO Specification for Movable Bridges is the base specification governing the analysis design of movable bridges.

<u>On Selection Of Alternates</u>

There are three basic bridge configurations to be considered at a navigable waterway crossing:

1. The low level movable bridge
2. The semi-high level movable bridge
3. The high level movable bridge

There are three basic types of movable bridges:

1. The vertical lift
2. The swing span
3. The bascule

Additional types of water crossings are the pontoon bridge and the ferry.

The economic factors in evaluating the alternative for crossing a waterway are extensive, and the data required satisfying a rigorous analysis is not readily available, or at least not easily quantified. However, reasonable estimates of this data often result in economic analyses which so heavily factor a particular alternate that significant errors in assumption will have little affect on the comparison.

High level fixed bridges are to be preferred unless the economics clearly indicate that a movable bridge would be significantly less expensive. Although lengthy approaches are required for high level bridges, they afford the following advantages: unrestricted flow of both marine and highway traffic, operators are not needed, less required maintenance, and lower susceptibility to marine collision. High levels of vehicular and marine traffic make the movable bridge alternate less tolerable.

Low level movable bridges provide for near grade crossing of highway traffic, with minimal bridge approaches. Every attempt should be made to provide sufficient clearance under the bridge to allow passage of 80% or more of all navigation, as well as all-small marine vessels, such as runabouts, without opening the bridge. These structures require complex electrical and mechanical equipment for operation of the span, along with operating personnel. Due to the closeness to the water, the probability of collision damage is greater than for a high level or semi-high level structure. Maintenance frequency and cost are relatively high compared to fixed bridges, as are the operating costs, which include electrical power and manpower.

Semi-high level movable bridges are difficult to justify economically because they incorporate the economic disadvantages of low level movable bridges, and, in part, the economic disadvantages of high level fixed bridges. Because they have long approach structures, the maintenance costs include those required for high level bridges, as well as those required for operating equipment. Semi-high level bridges do provide the advantage of passing most marine traffic without opening, which may justify placing an operator “on call” rather than requiring continuous operating status. However, potential damage to operating equipment and loss of operational integrity are factors which greatly increase repair cost compared to fixed structures with similar collision damage.

The traditional approach to bridge economics of comparing initial cost and choosing the least cost alternate to gain as many improvements as possible with the construction budget is not applicable when comparing fixed and movable structures. The significant long-term cost associated with operating and maintaining movable bridges impact operations and maintenance budgets in a way not associated with fixed structures, not to mention the inconvenience to the traveling public. Though these costs do not affect the current construction budget, they do affect future total budgets shared between maintenance, operations and construction. To account for this, the long-term costs should be incorporated over the life expectancy of the bridge alternates being considered. Economic analyses such as present-worth should be used with a typical life expectancy of 50 years.

Though economics are usually the most significant consideration, a particular site condition or service intent of a bridge may dictate a choice of an alternate other than the apparent most economical one. However, a rational economic analysis will give the Department and the public the needed knowledge of the additional cost required to satisfy any overriding peripheral issues controlling the choice of alternates.

Analysis

Movable bridges are designed to sustain an intricate set of load conditions in addition to those for fixed bridges. These loads simulate wind, traffic and impact conditions under which the bridge must operate. Provisions for adjustment to balancing and for anticipated malfunctions are considered in the design and planning of a movable bridge, to minimize the probability of in-service structural or mechanical damage. Accordingly, certain structural design practices for movable bridges tend to be more conservative than those allowed in the specifications for fixed bridges. These practices are derived from engineering judgment and experience, and are intended to assure the long term durability and safety of such structures.

1. The moving elements of a movable bridge, including the supporting substructure, should be designed by the working stress methods.

2. A fifth load configuration and an additional group load shall be incorporated into the design of swing span bridges. The load configuration is:

   a) "Case V: Unbroken Live Load - Bridge closed and considered as a continuous girder, but the live load placed so as not to cause negative reactions." [1]

   b) An additional group loading combines Case I and Case V. This combination represents a malfunction condition where the wedges fail to drive and the span is operating under live load applied such that the ends bear on the rest piers.

3. The general policy of providing for an additional 600 N/m^2 for future wearing surface will not be incorporated into the design of movable (lift, swing, bascule) span structures. If resurfacing is required, the rehabilitated surface will match the original grade causing no additional weight or adjustments to the counterweight. The plans must indicate in the General Notes sheet that these structures have not been designed for future wearing surface.

Design Details

1. Construction materials are strategically selected to achieve the most effective advantage in terms of strength, weight, and cost requirements. The deck (steel grid or concrete) of movable spans are chosen for light weight to minimize the

[1] Movable Bridge, volume 1, O. E. Hovoy, John Wiley and Sons, Inc. 1926, pp. 191-192

counterweights, strength of supporting elements, and the power to operate the span. Where the deck contributes to the counterweighing of the span, such as for short arm of an unequal arm swing span, or the tail side of the trunion on a bascule span, heavier decks such as concrete are chosen.

2. Where machinery must be located under steel grid floors, the steel grid should be partially filled with concrete to provide shelter from the roadway debris and weather.

3. On swing span bridges, the top of the pivot pier cap should be at an elevation that will clear the design high water sufficiently to prevent the machinery from getting wet. The desirable value is usually 0.30 meters above the 50 year high water elevation. Any value less than this must be balanced between the competing constraints.

4. The area around the anchorage beams for the hydraulic arm attachment shall be poured monolithically with the cap.

5. The sag in swing spans caused by differential temperature in the flanges must not be incorporated in the stress, deflection, and camber requirements for the span. However, this sag component will be incorporated into the end lift reactions.

6. The erection and construction sequence for the main girders of the steel plate girder swing spans shall be completely outlined in the details for the swing span. This information is normally shown adjacent to the camber diagrams and should read as follows:

Erection Notes

THE CONTRACTOR WILL BE REQUIRED TO SUBMIT DETAILED ERECTION DRAWINGS SHOWING THE SEQUENCE OF ERECTION AND THE FALSEWORK TO BE USED. THIS INFORMATION MUST BE SUBMITTED TO THE BRIDGE DESIGN ENGINEER WITH SUFFICIENT TIME TO ALLOW FOR CHECKING, CORRECTIONS, AND APPROVAL PRIOR TO ERECTION OF THE SPAN.

THE FALSEWORK SHALL BE PILE SUPPORTED AT BOTH ENDS AND AT THE FIELD SPLICED LOCATIONS OF THE MAIN GIRDERS. IT MUST PROVIDE ADEQUATE RIGIDITY AND STRENGTH TO SUPPORT THE ERECTION POSITION AND LOADS REQUIRED. THE ERECTION POSITION OF THE MAIN GIRDERS SHALL BE REGULARLY CHECKED AND MAINTAINED DURING THE ERECTION PROCESS. THE FALSEWORK SHALL BE DESIGNED TO ACHIEVE THE FOLLOWING STAGES:

A. THE MAIN GIRDERS SHALL BE ERECTED ON FALSEWORK SUPPORTING THEM IN THE POSITION OF THE CAMBER DIAGRAM.

B. THE CONNECTIONS FOR THE MAIN GIRDERS (FIELD SPLICES), FLOOR BEAMS, STRINGERS, AND LATERAL BRACING SHALL BE COMPLETED.

C. MAIN GIRDERS SHALL BE ALLOWED TO DEFLECT TO A POSITION ABOVE THE FINISH GRADE POSITION, SUCH THAT ITS ORDINATES ARE NO CLOSER THAN 25% OF THE END LIFT DEFLECTION ORDINATES ABOVE THE FINISH GRADE ORDINATES (WEDGES DRIVEN). IF THE MAIN GIRDERS DO NOT DEFLECT ENOUGH TO MAKE CONTACT WITH THE FALSEWORK, WHEN PROPERLY ADJUSTED FOR THIS POSITION, SHIMS SHALL BE ADDED TO PROVIDE FULL SUPPORT IN THE DEFLECTED POSITION.

D. THE COUNTERWEIGHT SHALL BE POURED AND THE GRID DECK PLACED IN POSITION BUT NOT WELDED TO THE STRINGERS.

E. THE MAIN GIRDERS SHALL BE ALLOWED TO DEFLECT TO THE FINISH GRADE ORDINATES WITH THE END LIFTED.

F. THE CONCRETE DECK SHALL BE PLACED AND THE BRIDGE RAILING CONNECTIONS COMPLETED, ASSURING THAT THE ENDS OF THE SPAN WILL NOT DEFLECT BELOW FINISH GRADE. THE GRID DECK SHALL BE WELDED TO THE STRINGERS.

G. UPON COMPLETION OF THE ERECTION OF THE MAIN SPAN (INCLUDING INSTALLATION OF THE BALANCE WHEELS, THE PLACEMENT OF THE ESTIMATED NUMBER OF BALANCE BLOCKS ON THE COUNTERWEIGHTS NECESSARY TO BALANCE THE SPAN, PUMP, AND ROLLERS), THE SUPPORTING FALSE WORK SHALL BE REMOVED.

H. THE FREE SWINGING SPAN SHALL BE PRECISELY BALANCED AND THE ORDINATES MEASURED IN THE MORNING PRIOR TO SUNRISE TO AVOID TEMPERATURE EFFECTS. THE ORDINATES SHALL BE COMPARED TO THE FINISH GRADE ORDINATES, WITH THE ENDS NOT LIFTED. THE ROLLER BASE ELEVATIONS SHALL BE SET TO PRODUCE THE END LIFT DEFLECTION OF THE SPAN AT CONSTANT TEMPERATURE.

I. THE HORIZONTAL BASE LINE SHALL BE ROTATED WHILE THE SPAN IS FREE SWINGING TO PROVIDE FOR EQUAL END LIFTS WITH DESIGN TEMPERATURE DEFLECTION. THE BALANCE WHEELS SHALL BE ADJUSTED TO CLEAR THE TRACK BY NOT MORE THAN 0.8 mm WHILE THE SPAN IS IN THIS POSITION.

J. THE ROLLER BASE RISERS AND RISER WALLS ON THE REST PIERS SHALL BE PLACED AND THE ROLLER BASES INSTALLED. CHECK THE END LIFT SYSTEM TO ENSURE ITS ABILITY TO LIFT TO THE FINAL ORDINATES WITHOUT EXCEEDING THE DESIGN PRESSURE.

K. THE APPROACH SPANS ADJACENT TO THE MAIN SPAN SHALL BE PLACED WITH FINISH GRADE AND END DAMS ADJUSTED AS REQUIRED TO MATCH THE COMPLETED MAIN SPAN WITH ENDS LIFTED.

COUNTERWEIGHTS:

THE CONTRACTOR WILL BE REQUIRED TO MAKE THREE (3) TEST BLOCKS IN THE PRESENCE OF THE ENGINEER, AS REQUIRED BY THE STANDARD SPECIFICATIONS. THE ENGINEER WILL BE NOTIFIED OF THE TIME AND PLACE THAT THE TEST BLOCKS ARE TO BE MADE. THE RESULTS OF THE TEST BLOCKS ALONG WITH THE COUNTERWEIGHT CALCULATIONS MUST BE SUBMITTED TO THE BRIDGE DESIGN ENGINEER, WITH SUFFICIENT TIME ALLOWED FOR CHECKING, CORRECTIONS, AND APPROVAL PRIOR TO ERECTION OF THE SPAN."

Special Requirements

1. The Department has a special way of presenting the mechanical and electrical drawing for movable bridges. This format must be followed on all projects, whether the plans are prepared in-house or by consultant engineers.

2. The operating house should be located with primary consideration for good visibility of the roadway, traffic gates, and the navigation channel. There not being any advantage to visibility, other criteria in order of importance are location of existing utilities and accessibility in open position on long arm (bobtail swing) downstream side. The designer should have the District Maintenance Engineer visit the site of the proposed bridge to recommend the location of the operating house. This is especially important when the alignment crosses a bend of the waterway.

3. The floor elevation of the operating house shall permit the standing operator to have a blind area of waterway 18 m, but no more than 30 m beyond the fascia of the bridge. This will require the floor elevation to be governed by the width of the structure.

4. When detailing the safety railing leading to the operators' house, it should be brought as close to the bridge rail as possible. The safety rail shall be continuous from the bridge to the house, so as to avoid any unsafe openings.

5. The access from the deck to the top of the pivot pier must be provided when the deck is in the open as well as closed positions. Platforms for the landings shall be provided with safety rails long enough to avoid accidents. Additionally, platforms for inspection and working areas of traffic gates, traffic barriers, and end lifts (swing spans) shall have safety rails as described above.

6. Access shall also be provided from the deck to the top of the rest piers. A platform may be required on the backside of the rest pier wall with a passageway through the wall, in order to provide adequate access. The designer should consult with the Bridge Maintenance Section in determining inspection requirements.

7. Traffic gates are located and striped in accordance with "Manual of Uniform Traffic Control Devisees for Streets and Highways" (MUTCD) published by the Federal Highway Administration (see section in the manual on "List of Specifications . . . .Bridges"). When not installed on structures, traffic gates are normally located 1.8 m from the edge of roadway or 0.6 m from the outer edge of a sidewalk when present. Traffic gates are normally located 50 m in advance of the movable span or its barrier, if present. Consideration must also be given to the visibility of the gates to the motorists when establishing their actual location.

8. Traffic warning signals are located and painted in accordance with MUTCD. When not installed on structures, they are normally located 1.8 m from the edge of roadways or 0.6 m from the outer edge of the sidewalk when present. Signals are normally located 15 m in advance of the traffic gates, and should not be placed behind the guardrail BCT. Additionally, curbs should not be used in front of the guardrail. Consideration must be given to the visibility of the signals to the motorists in establishing their actual location.

9. Navigation lights for bridges crossing navigable inland waterways controlled by the U.S. Coast Guard must be in conformance with their established rules. Consult the "Aids to Navigation" Manual published by the Coast Guard to locate navigation lights when required. Examples are given therein for different types of bridges, which must be followed. A sketch on letter-size paper, with a location map, elevation and plan view of the proposed bridge with navigation lights located and shown in the proper color, must be sent to the appropriate Coast Guard District for approval. If the bridge is not over a navigable waterway controlled by the Coast Guard, it must be determined if any local rules apply. If not, the navigation lights are installed according to the directions of the District Administrator.

10. Aerial beacons for structures that are controlled by the U.S. Department of Transportation, Federal Aviation Administration. Consult the "Obstruction Marking and Lighting" Manual published by the agency for regulations concerning height and location of proposed construction and need for aerial beacons. If the proposed construction appears to require aerial beacons or other obstruction markings, Federal Aviation Administration Form No. 7460-1 should be prepared along with a location map, elevation and plan views showing lights and/or markings, then sent to the FAA for comment and/or approval.

11. Submarine cables require a permit from the Coast Guard before work can begin. The Department obtains this permit from the Coast Guard before the work is started during the plan preparation phase. The permit request requires a sketch on letter-size paper showing the geographic locations, elevation and plan views of the proposed bridge with the submarine cable shown in red. This permit request is sent to the proper Coast Guard District for approval. It may be combined with the navigation light permit showing all information on the same sketch. A permit sketch is also necessary for adding or removing submarine cables on repair jobs. (consult the manual, "Aids to Navigation" published by the Coast Guard for complete information for permit applications)

12. The motor for the span is specified by the Electrical Engineering Unit with the torque, rpm, and size requirements provided by the Mechanical Engineering Unit. The latter specifies both size and type of smaller motors such as the barrier motor.

13. The operating house shall contain within it the switchboard, control desk, auxiliary electrical panels, lighting, receptacles, heating/cooling unit, office type desk and chair. In some instances it shall also contain one or all of the following: bathroom facilities, sewage treatment facility, central heating and air-conditioning, baseboard heating and emergency generator. Depending upon the equipment to be installed the operating house can be single story or two story with the lower deck either enclosed or open. The designer shall obtain information from the Bridge Maintenance and Electrical Design Units.